PLANT FOR PRODUCING COMPRESSED GAS AND METHOD FOR USING SAID PLANT

The present invention relates to a method for producing compressed fluid and to a compressed fluid production plant for implementing it.

By way of a known compressed-air production plant there is, for example, the one described in the article entitled: "Air comprimé, retour d'expérience sur une vente au mètre cube [compressed air, feedback on sales by the cubic meter]" published in ENERGIE PLUS, No. 224, dated April 15, 1999, the journal of "l'Association Technique Energie Environnement [Environment Energy Technical Association]". It comprises at least two compressors the delivery side of which is connected to a compressed air network; one of these compressors at least runs at a fixed speed and is sized such that it always runs at 100% capacity; another runs at a variable speed and is regulated in such a way that it tops up the fluid flow rate demanded. The latter compressor is switched on or off according to the pressure observed in the air network. When the installation comprises more than two compressors, just one is of variable output.

Now, this type of plant cannot be used economically over a wide range of fluid flow rates.

European patent application EP 1 249 675 describes a method for controlling a bank of compressors using a frequency converter. However, this method often entails a financial investment that is not really compatible with the anticipated energy saving, and it is conceivable only for the most top-of-the-range plants such as conditioned-air stations or refrigeration systems.

It is an object of the present invention to alleviate the aforementioned disadvantages and to propose a plant for supplying compressed fluid which is economical, particularly in terms of its power consumption. Another object is a plant for supplying compressed fluid which has a low maintenance cost.

In the context of its search to achieve the aforementioned objectives, the applicant company has unexpectedly discovered that the specific overall power consumption of a compressor plant can be significantly improved by implementing the device explained hereinafter.

This is why, according to a first aspect, the subject of the invention is a plant for producing a compressed fluid, comprising:

- n compressors, n being greater than or equal to 1, the delivery side of which is connected to a compressed fluid network,
- for each of the compressors, a connecting line connecting it to a power source,
- for each of the compressors, at least one switching means designed to trigger the change in status of each of the compressors,
- at least one pressure sensor designed to measure the pressure of the fluid in the compressed fluid network, and
- at least one control means designed to control one or other of the switching means,

characterized in that:

the singular or plural control means are connected to one or more individual actuating means for actuating each of the switching means, and

the singular or plural control means comprise one or more selection means able to select one or more compressors that are to be either started, or switched to idling, or switched to compressing, or switched off,

according to a predetermined selection protocol dependent on the pressure of said compressed fluid in said network.

A status is intended in the context of the present invention to mean, for each compressor, the following three statuses:
the compressor is switched off;
the compressor is idling;
the compressor is compressing.

The compressors used in the plant that is the subject of the present invention are preferably of the "all-or-nothing" type.

According to another preferred aspect of the present invention, the compressors are identical.

An "all-or-nothing" type compressor is mainly intended to denote the commercially available compressors categorized into this category and more specifically screw compressors.

A compressed fluid is to be understood as meaning a fluid whose total pressure is higher than one atmosphere and, more particularly: air, oxygen (O_2), nitrogen (N_2), argon (Ar), carbon dioxide (CO_2), carbon monoxide (CO), helium (He), nitrous oxide (N_2O), nitrogen monoxide (NO), mixtures of nitrous oxide and oxygen, of carbon dioxide and oxygen, of nitrogen and carbon monoxide, of helium and oxygen, such as, for example, the following mixtures: 50% by volume (v/v) N_2O + 50% v/v O_2, 5% v/v CO_2, 95% v/v O_2, 200 to 800 ppm NO in N_2, 78% He + 22% v/v O_2, 65% He + 35% O_2, 80% v/v He + 20% v/v O_2, or mixtures of nitrogen and carbon dioxide.

According to another preferred aspect of the present invention, the plant as defined hereinabove is a plant for producing compressed air.

A predetermined selection protocol is to be understood in the context of the present invention as meaning all the measurements and/or counts and/or calculations to be performed which generate the choice to change or alternatively not to change, the status of one or more of the compressors of said plant when the pressure observed in the compressed fluid network crosses one of the two limit values which are the lower threshold pressure (PSL) and the upper threshold pressure (PSH).

According to a first particular aspect of the present invention, the plant as defined hereinabove comprises from two to six compressors.

According to a second particular aspect of the present invention, the plant as defined hereinabove comprises at least one data acquisition means able to date and to determine each change of status of each compressor constantly or discontinuously over time.

According to this particular aspect of the present invention, the selection protocol is defined by all of the following parameters:

Variables set during initialization

- N_c: Maximum number of compressor start-ups per hour; this parameter is set by the compressor manufacturer.
- TMAV: Minimum idling before switch-off time;
- T_p: Time to run before forced switch-over;
- TMAV': Minimum idling before switch-to-compressing time.

Constantly calculated variable

- T: Date in current time.

Variables calculated for each compressor on each change of status of one of the compressors

- $T_{C/V}$: Date of the last change of status (compressing to idling) in the last hour;
- TMG: Total number of running hours since the plant was switched on (total running time);
- $T_1, T_2 \ldots T_{NC}$: Collection of start-up dates in the last hour from T_1 for the most recent start-up to T_{NC} for the oldest start-up;
- N_D: Number of start-ups performed in the last hour;
- TRDEM: Time to next available start-up.

According to an alternative form of the method that is the subject of the present invention, instead of monitoring the total running time TMG of each compressor, their total compressing time (TMCG) is monitored, this representing the number of hours of compressing since the plant was started up.

According to a preferred mode of this particular aspect, the control means comprise a programmable controller characterized in that it comprises a central unit comprising a memory and a computer program able to select, when the pressure P observed exceeds the pressure thresholds PSH or PSL, the compressor or compressors which, at a given moment t, need to be either started, or switched to idling, or switched to compressing, or switched off, by virtue of the selection protocol as defined hereinabove. This programmable controller possibly comprises means allowing it to be controlled remotely.

According to a fourth particular aspect of the present invention, in the plant as defined previously, the compressors are connected in parallel via their delivery side to a buffer reservoir of compressed fluid by means of a first linking pipe, said buffer reservoir being connected to the compressed fluid network by a second linking pipe equipped with a shut-off valve. The

first linking pipe is preferably equipped with a filter.

Another subject of the invention is a method for producing a compressed fluid using the plant as defined hereinabove, characterized in that it comprises, in the course of time, one or other of the following operating steps:

(a) - when the pressure of the fluid in the compressed fluid network downstream of said plant lies in a range of values ranging between the upper pressure threshold PSH and the lower pressure threshold PSL, the pressure of the fluid in said network is maintained within this range of values by means of at least one of the compressors of the plant;

(b) - when the pressure of the fluid in said network drops below PSL for a parametrizable length of time,

(i) - either just one of the compressors of the plant is switched off, with the others compressing, in which case said switched-off compressor is switched on and switched to compressing;

(ii) - or several of the compressors of the plant are switched off, with the others compressing, in which case the switched-off compressor whose number of start-ups per hour in the last hour (N_D) is the lowest is switched to compressing and, if several of the switched-off compressors have this same minimum (N_D), the one whose total running time (TMG) is the shortest is switched to compressing;

(iii) - or all the compressors of the plant are switched off, in which case the switched-off compressor whose (N_D) is the lowest is switched to compressing and, if several of the switched-off compressors have this same minimum (N_D), then the one whose (TMG) is the shortest is switched to compressing;

(iv) - or just one of the compressors of the plant is idling, the others compressing or being switched off, in which case said idling compressor is switched to compressing;

(v) - or several of the compressors of the plant are idling, the others compressing or being switched off, in which case this idling compressor whose time to next available start-up (TRDEM) is the longest is switched to compressing and, if several of the idling compressors have this same maximum (TRDEM), then the one whose (N_D) is the highest is switched to compressing and, if several of the idling compressors have this same maximum (TRDEM) and this same maximum (N_D), then the one whose (TMG) is the shortest is switched to compressing;

(vi) - or all the compressors of the plant are idling, in which case the idling compressor whose (TRDEM) is the longest is switched to compressing and, if several of the switched-off compressors have this same maximum (TRDEM), then the one whose (N_D) is the highest is switched to compressing and, if several of the switched-off compressors have this same maximum (TRDEM) and this same maximum (N_D), then the one whose (TMG) is the shortest is switched to compressing;

(c) - when the fluid pressure in said network becomes higher than PSH for a parametrizable length of time,

(i) - either just one of the compressors of the plant is compressing, the others being switched off or idling, in which case said compressor is switched to idling;

(ii) - or several of the compressors of the plant are compressing, the others being switched off or idling, in which case the compressing compressor whose number of available start-ups per hour (N_C-N_D) is the highest is switched to idling and, if several of the compressing compressors have this same maximum number (N_C-N_D), then the one whose TMG is the longest is switched to idling;

(iii) - or all the compressors of the plant are compressing, in which case the compressing compressor whose number of available start-ups per hour (N_C-N_D) is the highest is switched to idling and, if several of

the compressing compressors have this same maximum number (N_C-N_D), then the one whose TMG is the longest is switched to idling.

In the method as defined hereinabove, the number N_C is generally between 2 and 8.

If we consider that N_C is determined on the basis of a uniform distribution of the start-ups of the compressor in a given hour, then a time for which the compressor is switched off and cannot be re-started can be determined. This time, termed the time to next available start-up, or TRDEM, expressed in hours, is therefore less than $(1/N_C)$h. TRDEM is equal to 0 when there has been no start-up in the previous hour.

It is generally acknowledged that a compressor cannot switch directly from the compressing status to the switched-off status without remaining in the idling status for a minimum period of time, here termed the minimum idling before switch-off time or TMAV.

In the method as defined hereinabove, TMAV is generally greater than or equal to 30 seconds.

In the method as defined hereinabove, the TMG or total running time expresses the number of hours for which a given compressor has been running since the plant was started up.

According to a third particular aspect of the method as defined hereinabove, when a compressor has been idling for a length of time greater than TMAV, it is switched off.

According to a fourth particular aspect of the method as defined hereinabove, when, in the plant, at least one of the compressors is switched off, and at least one of the compressors is compressing, when the time

since the last start-up of said compressing compressor is greater than a switch-over time termed T_P, and its TMG is greater than the TMG of the switched-off compressor, the switched-off compressor is switched to compressing and the compressing compressor is switched off.

The method as described hereinabove is particularly suited to the production of compressed air.

According to a final aspect of the invention, a subject of this invention is a computer program for carrying out the method as defined hereinabove.

The invention will be better understood from reading the description which will follow, given solely by way of example and made with reference to the attached drawings in which:

- figure 1 is a schematic view of a compressed fluid production plant according to the invention; and
- figure 2 represents diagrams showing the changes in the pressure of the fluid over time and the corresponding regulation of a compressor.

This plant 2 comprises three compressors 4, 6, 8, each equipped with a switching means 32, 34 and 36 able to switch them into one of the three statuses that are switched off, idling and compressing, which are connected in parallel to the inlet 10 of a buffer reservoir 12 of compressed fluid by means of a first linking pipe 14 equipped with a filter 16. An outlet 18 of the buffer reservoir 12 is connected to a compressed air user network (not depicted) by means of a second linking pipe 20 equipped with a shut-off valve 22.

The compressors 4, 6, 8 are lubricated screw compressors. Such compressors are, for example, compressors of the DSD 201/7.5 bar type marketed by KAESER.

The plant 2 further comprises an electric power source, in this instance a three-phase power source 24.

The plant 2 comprises three first three-wire connecting lines 26, 28, 30. Each of the first connecting lines 26, 28, 30 connects one of the compressors 4, 6, 8 to the power source 24.

A pressure sensor 54, for sensing the pressure of the fluid is located downstream of the compressors 4, 6, 8 in the fluid network, for example in the buffer reservoir 12.

The plant 12 further comprises a control device, in this instance a programmable controller CMD.

This control device CMD comprises an input 56 which is connected to the pressure sensor 54 by a sensor line 58, so as to observe the fluid pressure P in the fluid network.

The controller CMD further comprises three outputs 60, 62, 64 which are connected to first 66, second 68 and third 70 control lines for controlling the switching means 32, 34 and 36.

The outputs 60, 62, 64 and the associated control lines 66, 68, 70 are designed to control the switching over of the compressors 4, 6 and 8.

The outputs 60, 62, 64 are slaved by a central processing unit CPU of the controller CMD according to the fluid pressure P.

Aside from the central processing unit CPU, the programmable controller CMD comprises a memory MEM in which the upper pressure threshold PSH and lower pressure threshold PSL are stored, together with all

the acquired data relating to the parameters and variables mentioned hereinabove and a program PRG for controlling the plant able, when the observed pressure P crosses the pressure thresholds PSH or PSL, to select that or those compressors which, at a given moment t, need to be either started up, or switched to idling, or switched to compressing, or switched off.

In addition, the memory MEM stores, for each of the compressors 4, 6, 8, the total running time of the associated compressor 4, 6, 8.

The program PRG used in the controller CMD controls the switching means 32, 34 and 36 according to an exclusive connection mode.

The controller CMD is also equipped with detection means for detecting a failure of one of the components of the plant 2.

These means are connected to a telephone line 80 so that the maintenance personnel can be alerted in the event of a failure.

Figure 2 depicts an example of the variation, over a space of time of one hour, in the pressure P obtaining in the air network and two diagrams of the changes in status of three compressors in parallel (CO1, CO2, CO3) according to the invention (new control law) and according to the state of the art (old law).

The abscissa of the two diagrams represent the various statuses of the three compressors: (MC compressing; MV: idling; SB: switched off).

This figure reveals that the method according to the new control law makes it possible to eliminate most of the idling time that exists in the method according to

the old control law (regions shaded gray in the diagram).

On completion of the experiment described hereinbelow, it was found that the plant according to the invention was able to save up to about 10% of power by comparison with a plant of the state of the art.